Dalziel High School
Chemistry Department

1997 CSYS

CERTIFICATE OF SIXTH YEAR STUDIES 1997

MONDAY, 19 MAY
9.30 AM – 12.00 NOON

CHEMISTRY
Paper

All questions should be attempted.

Necessary data will be found in the Chemistry (Revised) Higher Grade and Certificate of Sixth Year Studies Data Booklet (1992 edition) which is provided.

1. $Cr(g) \rightarrow Cr^{3+}(g) + 3e^-$

The energy required for this change, per mole of chromium(III) ions, is

A 1753 kJ

B 1977 kJ

C 3000 kJ

D 5259 kJ.

2. What type of bonding exists in the element which melts above 3800 K and forms a gaseous oxide?

A Covalent (polar)

B Covalent (non-polar)

C Metallic

D Ionic

3. $2Cu^{2+}(aq) + 4I^-(aq) \rightarrow 2CuI(s) + I_2(s)$

$2S_2O_3^{2-}(aq) + I_2(s) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$

$50\,cm^3$ of $0{\cdot}02\ mol\,l^{-1}$ $CuSO_4$ solution are added to excess KI solution. What volume of $0{\cdot}10\ mol\,l^{-1}$ $Na_2S_2O_3$ solution is required to react completely with the liberated iodine?

A $5\,cm^3$

B $10\,cm^3$

C $25\,cm^3$

D $50\,cm^3$

4. The addition of silver(I) nitrate solution to a solution of X gave a white precipitate which dissolved in dilute nitric acid. Which of the following ions was present in X?

A Carbonate

B Chloride

C Nitrate

D Iodide

5. Which of the following is an accepted analytical method?

A Determination of the concentration of Ca^{2+} ions by titration with acidified potassium permanganate

B Determination of the concentration of Ni^{2+} ions by titration with EDTA

C Determination of the concentration of NO_3^- ions using barium chloride

D The use of solid sodium hydroxide to standardise hydrochloric acid

6. Which of the following is **not** a form of electro-magnetic radiation?

A α–radiation

B γ–radiation

C U.V.–radiation

D X–rays

7. Which of these electron arrangements breaks Hund's rule of maximum multiplicity?

A 4s ⇅ 3d | ↑ | ↑ | ↑ | ↑ |

B 4s ⇅ 3d ⇅ | ↑ | ↑ | ↑ |

C 4s ⇅ 3d ⇅ | ⇅ | ↑ | ↑ | ↑ |

D 4s ⇅ 3d | ↑ | ↑ | ↑ | ↑ | ↑ |

8. The electronic configuration of a krypton atom is

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^{10}\ 4s^2\ 4p^6$.

Which of the following ions does **not** have this configuration?

A Zr^{3+}

B Sr^{2+}

C Se^{2-}

D As^{3-}

[Turn over

9. $^{235}_{92}U$ is formed by the radioactive decay process involving the overall loss of one alpha and two beta particles.

Which one of the following was the starting point of this decay process?

A $^{231}_{90}Th$

B $^{239}_{92}U$

C $^{239}_{93}Np$

D $^{239}_{94}Pu$

10. How many moles of H_3PO_4 will be neutralised by $20\,cm^3$ of $0{\cdot}2\ mol\,l^{-1}$ of $Ca(OH)_2$?

A $2{\cdot}0 \times 10^{-3}$

B $2{\cdot}67 \times 10^{-3}$

C $4{\cdot}0 \times 10^{-3}$

D $6{\cdot}0 \times 10^{-3}$

11. In which of the following will an increase in pressure lead to an increase in concentration of the product(s)?

A $H_2(g) + Cl_2(g) \rightleftharpoons 2HCl(g)$

B $2N_2O_5(g) \rightleftharpoons 2N_2O_4(g) + O_2(g)$

C $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

D $N_2O_4(g) \rightleftharpoons 2NO_2(g)$

12. At T_b, the boiling point of a liquid

$$\Delta S_{vaporisation} = \frac{\Delta H_{vaporisation}}{T_b}$$

For many liquids

$$\Delta S_{vaporisation} = 88\,J\,K^{-1}\,mol^{-1}(approx)$$

If this value was true for water ($\Delta H_{vaporisation} = 40{\cdot}6\,kJ\,mol^{-1}$), the predicted boiling point of water would be

A 0·46 K

B 2·16 K

C 373 K

D 461 K.

13. The standard enthalpy of formation of solid calcium nitrate at 298 K is $-937\,kJ\,mol^{-1}$. Which of the equations below correctly represents this formation process?

A $Ca^{2+}(aq) + 2NO_3^-(aq) \rightarrow Ca(NO_3)_2(s)$

B $Ca(g) + N_2(g) + 3O_2(g) \rightarrow Ca(NO_3)_2(s)$

C $Ca(s) + N_2(g) + 3O_2(g) \rightarrow Ca(NO_3)_2(s)$

D $Ca(s) + 2NO_3^-(aq) \rightarrow Ca(NO_3)_2(s)$

14. Which of the following processes is exothermic and has a positive ΔS value?

A Snow flakes forming

B Ammonia gas and hydrogen chloride gas forming solid ammonium chloride

C Ethoxyethane (diethyl ether) evaporating

D Carbon burning

15. The following data refer to initial reaction rates obtained for the reaction

$$X + Y + Z \rightarrow \text{products}$$

	RELATIVE CONCENTRATIONS			RELATIVE INITIAL RATE
	[X]	[Y]	[Z]	
Expt. 1	1·0	1·0	1·0	0·3
Expt. 2	1·0	2·0	1·0	0·6
Expt. 3	2·0	2·0	1·0	1·2
Expt. 4	2·0	1·0	2·0	0·6

These data fit the rate equation

A Rate = k [X]

B Rate = k [X] [Y]

C Rate = k [X] $[Y]^2$

D Rate = k [X] [Y] [Z].

16. $N_2 + 3H_2 \rightleftharpoons 2NH_3$

The process described by the equation above is used to manufacture ammonia. Which of the following data would **not** be useful in calculating whether the forward reaction is feasible at a given temperature?

A $\Delta H_f(NH_3) = -46{\cdot}2\,kJ\ mol^{-1}$

B $E_A = 300\,kJ\ mol^{-1}$

C $S°(H_2) = 131\,J\,K^{-1}\ mol^{-1}$

D $S°(NH_3) = 193\,J\,K^{-1}\ mol^{-1}$

17. A cell consists of inert electrodes in half cells whose Standard Reduction Potentials are shown below.

$MnO_4^{2-}(aq) + 4H^+(aq) + 2e^- \rightarrow MnO_2(s) + 2H_2O(\ell)$

$E° = 2{\cdot}26V$

$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$

$E° = 0{\cdot}77V$

What would the potential difference of this cell be, under standard conditions?

A 0·72V

B 1·49V

C 3·03V

D 3·80V

18. $ClO_3^-(aq) + 6H^+(aq) + ne^- \rightarrow Cl^-(aq) + 3H_2O(\ell)$

What value of n is required to balance the above equation?

A 4

B 5

C 6

D 7

19. The reaction A + 2B → C has a rate law of the form

Rate = k [A] [B].

If the reaction proceeds by a two step process, then the rate-determining step might be

A A + B → intermediate

B B + B → intermediate

C A + B → C

D B + AB → C.

20. $O_2(g) + 2H^+(aq) + 2e^- \rightleftharpoons H_2O_2(aq)\ E° = 0{\cdot}68V$

Predict which of the following reagents (under standard conditions) would react with hydrogen peroxide solution to release oxygen.

A Sodium sulphite solution

B Powdered zinc metal

C Acidified dichromate solution

D Copper (II) sulphate solution

21. The second ionisation energy of magnesium is represented by

A $Mg^{2+}(g) \rightarrow Mg^{3+}(g) + e^-$

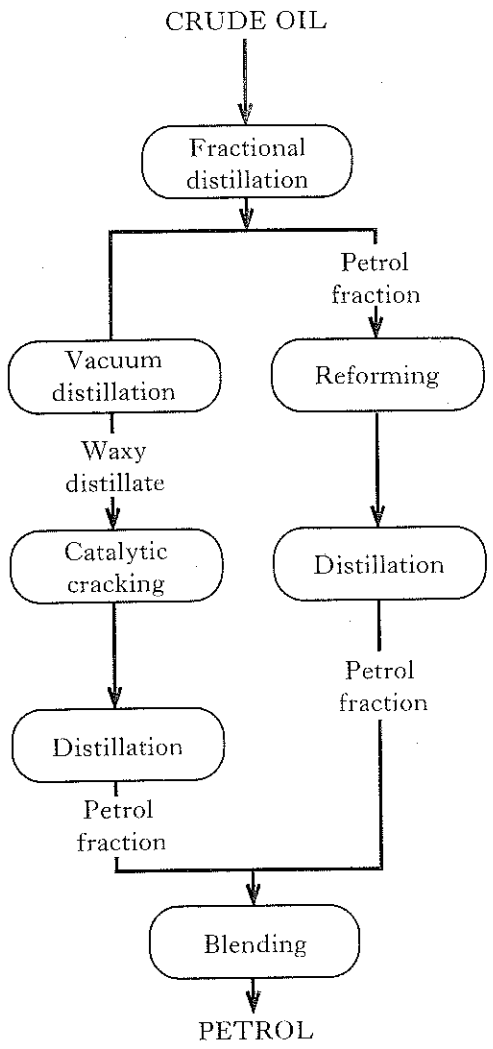
B $Mg(s) \rightarrow Mg^{2+}(g) + 2e^-$

C $Mg(g) \rightarrow Mg^{2+}(g) + 2e^-$

D $Mg^+(g) \rightarrow Mg^{2+}(g) + e^-$

[Turn over

22. Examine the information in the diagram below.



Which of the following statements is true?

A Catalytic cracking allows more petrol to be obtained than was in the original crude oil.

B Vacuum distillation breaks down long chain hydrocarbons into shorter chains.

C Reforming improves the quality of the petrol fraction by reducing the percentage of aromatic compounds in the fraction.

D Reforming improves the quality of the petrol fraction by increasing the percentage of unbranched hydrocarbons in the fraction.

23. The enthalpy changes for two reactions are shown.

$2Cr(s) + 1\frac{1}{2}O_2(g) \rightarrow Cr_2O_3(s)$ $\quad \Delta H = -1130\,kJ$

$C(s) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ $\quad \Delta H = -110\,kJ$

What is the enthalpy change for the following reaction?

$3C(s) + Cr_2O_3(s) \rightarrow 2Cr(s) + 3CO(g)$

A $-1460\,kJ$

B $-800\,kJ$

C $+800\,kJ$

D $+1020\,kJ$

24. Which of the following can behave as an electrophile?

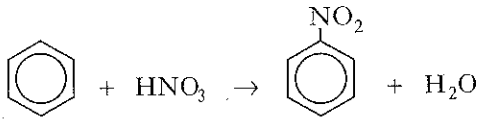
A $C_2H_5NH_2$

B HS^-

C NH_3

D NO_2^+

25. In the reaction between benzene and nitric acid in the presence of concentrated sulphuric acid



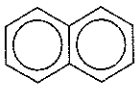
A the benzene molecule is acting as an electrophile

B the NO_3^- ion is acting as a nucleophile

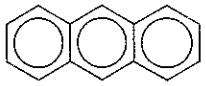
C the NO_2^+ ion is acting as an electrophile

D the HNO_3 is being oxidised.

26. Naphthalene and anthracene are examples of polycyclic aromatic hydrocarbons.

Naphthalene: Structural formula: 

Molecular formula: $C_{10}H_8$

Anthracene: Structural formula: 

The molecular formula of anthracene is

A $C_{14}H_{10}$

B $C_{12}H_{10}$

C $C_{14}H_{12}$

D $C_{12}H_{12}$.

27. Which alcohol gives a ketone on oxidation?

A 4-methylpentan-2-ol

B hexan-1-ol

C 2,3-dimethylbutan-2-ol

D 3,3-dimethylbutan-1-ol

28. The formula $C_4H_{10}O$ could represent an alcohol (C_4H_9OH) or an ether ($(C_2H_5)_2O$).

Which of the following statements would **not** be true about **both** compounds?

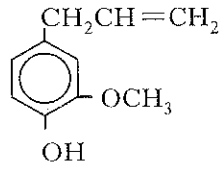
A They can be made by nucleophilic substitution from a haloalkane.

B They are used as solvents.

C They are flammable.

D They have hydrogen bonds between their molecules.

Questions 29 and 30 refer to a compound called eugenol.

Structural formula 

29. Eugenol is the main constituent of clove oil. Clove oil is first treated with KOH(aq) in order to isolate the eugenol.

Which part of the structure of eugenol is most likely to be involved in the reaction?

A The $-OCH_3$ group

B The aromatic ring

C The —OH group

D The unsaturated side-chain

30. In the infra-red spectrum of eugenol, an absorption due to the stretching of a carbon/oxygen bond would be expected near

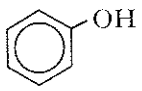
A $1275\ cm^{-1}$

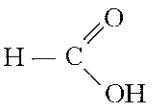
B $1700\ cm^{-1}$

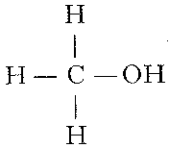
C $1730\ cm^{-1}$

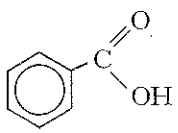
D $2775\ cm^{-1}$.

31. Which of the following is least acidic?

A 

B 

C 

D 

32. Which of the following statements about benzene is correct?

A Benzene readily attracts nucleophilic reagents.

B The benzene molecule contains carbon-carbon bonds of two different lengths.

C Benzene decolourises bromine water quickly.

D The benzene molecule is planar.

33. $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

Removing the sulphur trioxide produced in the above system will

A decrease the value of the equilibrium constant

B decrease the concentration of SO_2 only

C decrease the concentration of SO_2 and O_2

D increase the value of the equilibrium constant.

34. Which of the following forward reactions has the units of $K_c = mol^2 l^{-2}$?

A $2SO_2(g) + O_2(g) \rightleftharpoons 2SO_3(g)$

B $2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$

C $2NO(g) + O_2(g) \rightleftharpoons 2NO_2(g)$

D $2NO_2(g) \rightleftharpoons N_2O_4(g)$

35. A solution of sulphuric acid is diluted until it has a concentration of 1×10^{-5} mol l^{-1}.

Assuming the acid is completely ionised, the pH would then be

A 1

B 4·3

C 4·7

D 5.

36. The dissociation constant for water (K_w) varies with temperature.

$K_w = 0{\cdot}64 \times 10^{-14}$ mol^2 l^{-2} at 18 °C

$K_w = 1{\cdot}00 \times 10^{-14}$ mol^2 l^{-2} at 25 °C

From this information we can deduce that

A the ionisation of water is exothermic

B the pH of water is greater at 25 °C than at 18 °C

C only at 25 °C does the concentration of H^+ equal the concentration of OH^-

D water will have a greater electrical conductivity at 25 °C than at 18 °C.

37. In which of the following complexes is the transition metal in the +1 oxidation state?

A $K_3[CuF_6]$

B $K_6[Mn_2O_6]$

C $K_4[Ni_2(CN)_6]$

D $Ba_3[Co_2(CN)_{10}]$

38. $V^{2+}(aq) \rightarrow VO_2^+(aq)$

This change involves

A oxidation, with the loss of 1 electron

B reduction, with the gain of 1 electron

C oxidation, with the loss of 3 electrons

D reduction, with the gain of 3 electrons.

39. $P + Q \rightarrow R$

The rate equation for this reaction is Rate = k[P] $[Q]^2$.

If the concentration of P and Q are both doubled, the rate will increase

A 2 times

B 4 times

C 6 times

D 8 times.

40. Solid ammonium dichromate decomposes to produce chromium(III) oxide, nitrogen and water. The complete decomposition of one mole of ammonium dichromate would give

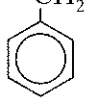
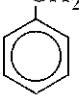
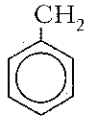
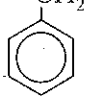
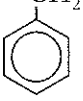
A a total of one mole of all the products

B 3·0 moles of water

C 2·0 moles of chromium(III) oxide

D [illegible] moles of nitrogen

41. The boxes in the grid below contain certain aromatic compounds.

A 	B 	C 
D 	E 	F 

Identify the reactant and the product when the following reagents are used:

(*a*) Al_2O_3 and heat;

(*b*) NaOH(aq);

(*c*) KCN followed by dilute HCl.

42. The boxes in the grid below show atoms and ions of certain transition metals.

A Ti^{3+}	B V	C Mn^{2+}
D Fe^{3+}	E Co^{2+}	F Ni

(*a*) Identify the **two** particles which have the same electronic configuration.

(*b*) Identify the particle(s) which has (have) 3 unpaired electrons.

43. The boxes in the grid below show operations used in the extraction of metals from their ores.

A Convert the ore to the chloride	B Mix with another substance to reduce the melting point of the ore	C Heat the ore with carbon
D Electrolyse the melt	E Heat the ore in air	F Displace the metal with a more reactive one

Which operation or combination of operations from the grid should be chosen to enable each of the metals below to be obtained from its ore on an economic industrial scale?

(*a*) Titanium from TiO_2

(*b*) Aluminium from Al_2O_3

Marks

1. The data shown in the table below apply at 298K.

Substance	$\Delta H_f°$/kJ mol^{-1}	S°/J K^{-1}mol^{-1}
$NH_4Cl(s)$	−315·0	94·6
$NH_3(g)$	−46·2	193·0
$HCl(g)$	−92·3	187·0

The thermal decomposition of ammonium chloride is represented by the equation

$$NH_4Cl(s) \rightleftharpoons NH_3(g) + HCl(g)$$

Use the data to predict the **minimum** temperature at which this decomposition becomes thermodynamically feasible. **(4)**

2. Excess iron(III) nitrate was added to 40·0 cm^3 of 0·10 mol l^{-1} potassium iodide solution and the iodine formed was titrated with sodium thiosulphate solution. The volume required for complete reaction was 15·0 cm^3. The reaction can be represented by the equation

$$2S_2O_3^{2-}(aq) + I_2(aq) \rightarrow S_4O_6^{2-}(aq) + 2I^-(aq)$$

(*a*) Write the redox equation for the reaction between iron(III) ions and iodide ions. **1**

(*b*) Calculate the number of moles of iodine produced from the potassium iodide. **2**

(*c*) Calculate the concentration of the sodium thiosulphate solution. **2**

(*d*) State how you could detect the end point of the titration. **1**

(6)

3. The table below gives information about three compounds containing fluorine.

Fluorine compound	Shape	Bond angle
$BF_3(g)$		120°
$CF_4(g)$	tetrahedral	109·5°
$NF_3(g)$	pyramidal	107°

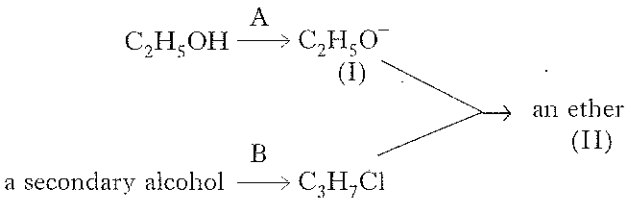
(*a*) What is the shape of the BF_3 molecule? **1**

(*b*) In terms of electron pair repulsions, account for the difference in bond angle between CF_4 and NF_3. **2**

(3)

Marks

4. Consider the reaction sequence outlined below.



(*a*) Give the name for the ion (I). **1**

(*b*) Name

(i) reagent A,

(ii) reagent B. **2**

(*c*) Draw the full structural formula for compound (II). **1**

(4)

5.

	$\Delta H/kJ\ mol^{-1}$
Enthalpy of sublimation of Ba(s)	176
Enthalpy of formation of $BaCl_2(s)$	–860
Electron gain enthalpy of Cl(g)	–349

(*a*) Use the data in the table above and the information on pages 11 and 12 of the Data Booklet to sketch the Born-Haber cycle corresponding to the equation

$$Ba(s) + Cl_2(g) \longrightarrow Ba^{2+}(Cl^-)_2(s)$$

Give the name for each enthalpy change shown on your sketch. **3**

(*b*) Use your sketch to calculate the lattice enthalpy of formation for $Ba^{2+}(Cl^-)_2(s)$. **3**

(6)

6. As a result of acid rain, a small loch of volume 10^{10} litres has a pH of 4·5.

(*a*) What is the hydrogen ion concentration of the loch? **1**

(*b*) How many moles of hydrogen ions are present in the loch? **1**

(*c*) Calculate the mass of pure calcium carbonate required to adjust the pH of the loch from 4·5 to 6·0. **4**

(6)

[Turn over

Marks

7. The table below gives information about complex ions containing vanadium.

Ion	Colour
$[V(H_2O)_6]^{2+}$	violet
$[V(H_2O)_6]^{3+}$	green
$[VO]^{2+}$	blue
$[VO_2]^{+}$	

(*a*) Determine the oxidation number of vanadium in the ions $[VO_2]^+$ and $[V(H_2O)_6]^{2+}$. 2

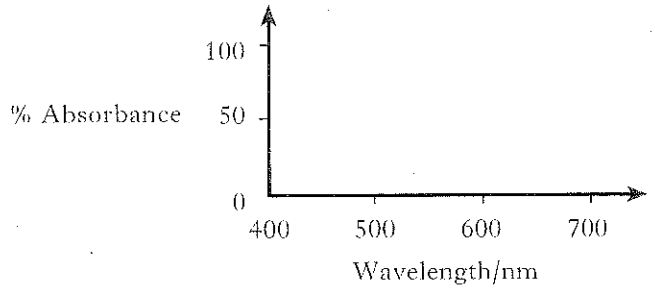
(*b*) Name and draw the shape of the green complex ion, $[V(H_2O)_6]^{3+}$. 2

(*c*) (i) Give the electronic configuration for vanadium in the $[VO_2]^+$ ion.

(ii) Suggest why you would predict this ion to be colourless. 2

(*d*) Light of wavelength varying from 400 to 700 nm is passed through a solution containing $[VO]^{2+}$ ions. Copy the axes shown and draw the **absorption spectrum** that you would expect to obtain. (Page 10 of your Data Booklet may be helpful.) 1

(7)



8. The Haber Process is represented by the equation

$$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g) \qquad \Delta H^\circ = -92 \text{ kJ mol}^{-1}$$

2·0 moles of each reactant were allowed to react and come to equilibrium in a 1 litre container at 400 K. At equilibrium, 0·4 moles of ammonia were formed.

(*a*) Write the expression for the equilibrium constant, K, for this reaction. 1

(*b*) Calculate

(i) the equilibrium concentrations of both nitrogen and hydrogen, 2

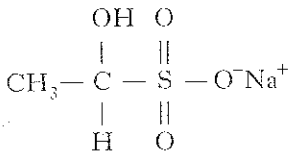
(ii) the value of the equilibrium constant at this temperature. 1

(*c*) Explain what will happen to the value of K, if the temperature is now raised to 600 K. 2

(6)

Marks

9. Ethanal (bp 294 K) is reacted with a saturated solution of sodium hydrogensulphite ($NaHSO_3$) for 30 minutes. The product of this "bisulphite" reaction is the sodium salt of hydroxyethane sulphonic acid. The structure of the salt is shown below.



(*a*) What type of chemical reaction occurs between the ethanal and the sodium hydrogensulphite solution? 1

(*b*) In practice, after separation of the sodium salt, purification and drying, the yield is found to be less than the theoretical value. Suggest **two** reasons for this fact. 2

(*c*) State how you could determine whether the crystalline product is pure. 1

(4)

10. A 12 V car battery has six electrochemical cells, consisting of lead electrodes in sulphuric acid, connected in series. The reactions that occur at the electrodes in each cell are

$$Pb(s) \longrightarrow Pb^{2+}(aq) + 2e^- \qquad E^\circ = +0{\cdot}13\,V$$

$$PbO_2(s) + 4H^+(aq) + 2e^- \longrightarrow Pb^{2+}(aq) + 2H_2O(\ell) \qquad E^\circ = +1{\cdot}47\,V$$

(*a*) When a cell is operating under standard conditions, determine

(i) the potential difference (e.m.f.) expected from the cell, 1

(ii) the standard free energy change for the cell reaction. 3

(*b*) Suggest why, in practice, the potential difference (e.m.f.) obtained from **each** cell in the battery is different from your answer to (*a*)(i). 1

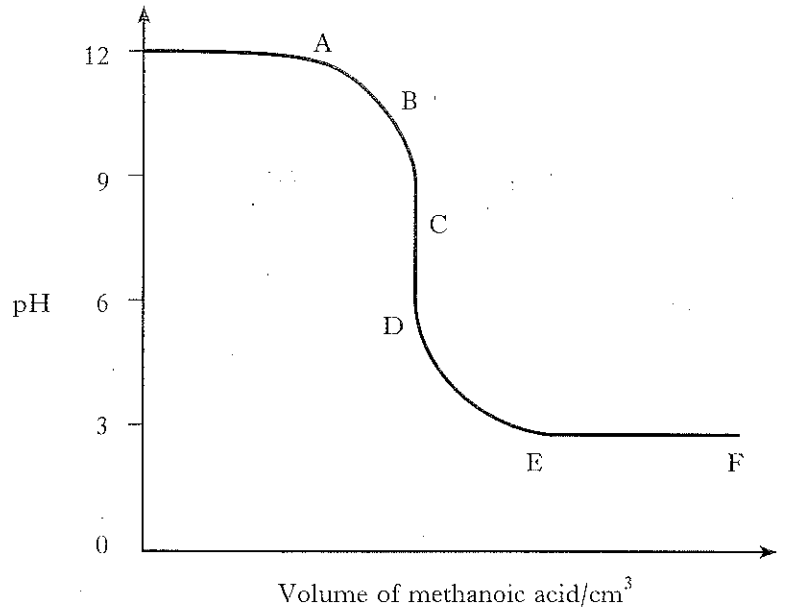
(*c*) If the battery is discharged for too long, a white precipitate forms around each electrode. Name the white precipitate. 1

(6)

[Turn over

Marks

11. When a pH electrode and meter are used to follow the titration between solutions of sodium hydroxide and methanoic acid, the following pH graph is obtained.



(*a*) Which one of the letters A to F corresponds to the point where the alkali is completely neutralised? **1**

(*b*) Which of the following indicators could be used to detect the neutral point? **1**

Indicator	pH Range
methyl orange	3·0–4·4
methyl red	4·2–6·3
phenol red	6·8–8·4
alizarin yellow R	10·0–12·0

(*c*) If the titration is stopped between E and F, the resulting solution acts as a buffer.

(i) Why can this solution act as a buffer? **1**

(ii) Explain how the pH of the buffer solution remains constant when a little more acid is added. **2**

(5)

Marks

12. The reaction

$$H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$$

follows *first order kinetics* with respect to both iodine and hydrogen.

When studied at different temperatures, the data shown in the table below were obtained. The data could be used to determine the Activation Energy for the forward reaction.

Temperature/K	Rate Constant/l $mol^{-1}s^{-1}$
556	$4{\cdot}45 \times 10^{-5}$
575	$1{\cdot}37 \times 10^{-4}$
629	$2{\cdot}52 \times 10^{-3}$
666	$1{\cdot}41 \times 10^{-2}$
700	$6{\cdot}43 \times 10^{-2}$
781	1·34

(*a*) Write the rate equation for the reaction. **1**

(*b*) Calculate the initial rate of reaction at 700 K, if the initial concentrations of both iodine and hydrogen are 0·5 mol l^{-1}. **2**

(*c*) The data show that the rate constant increases with temperature.

Explain this trend by sketching the distribution of kinetic energies among the reactant molecules at two different temperatures. Use the same set of axes for the two graphs and a single line to represent the energy of activation for the reaction. **3**

(6)

[Turn over

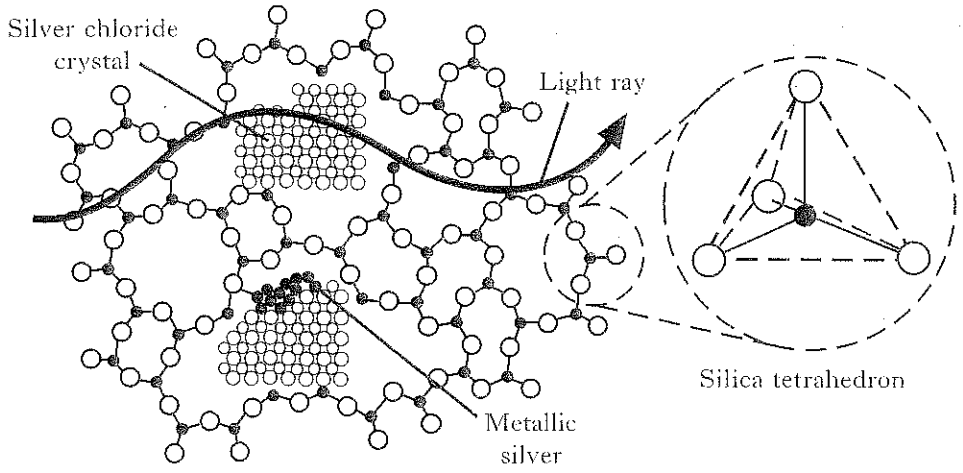
13. This article is adapted from pages 4–6 of *Chem Matters*, December 1989.

Automatic Sunglasses

Photochromic glass, that darkens in response to light, relies on the light sensitivity of a class of compounds known as silver halides that are dispersed in the glass. This is the same family of compounds used to make photographic film, and the chemical reactions are much the same. However once photographic film has been darkened by exposure and developing, it can't be reversed. The silver halide dispersed in photochromic glass, however, will decompose and reform indefinitely.

The basic unit of both sand and glass is a *tetrahedron* that consists of a silicon atom (solid circle) covalently bonded to four oxygen atoms (open circles), shown in the diagram below. Each tetrahedron is joined to others by sharing a common oxygen atom. In sand the tetrahedrons are arranged in an orderly, crystalline pattern but in glass, an amorphous substance, they are jumbled and disordered.

Photochromic glass contains crystals of silver chloride trapped between the silica tetrahedrons. This is shown in the diagram below.



The energy of the ultraviolet light causes the ions in the microcrystals of AgCl (consisting of a lattice of Ag^+ and Cl^- ions) to exchange electrons and produce free atoms of silver and chlorine.

$$Cl^- + \text{light} \rightarrow Cl + e^- \qquad \text{followed by} \qquad Ag^+ + e^- \rightarrow Ag$$

To keep the reaction from immediately going into reverse, a few ions of Cu^+ are present within the silver chloride crystal to react with the liberated chlorine atoms.

$$Cu^+ + Cl \rightarrow Cu^{2+} + Cl^-$$

The silver atoms migrate to the surface of the silver chloride crystal and aggregate into small, colloidal crystals of silver metal. Some of the electrons within the metallic silver are mobile and this permits them to interact with the electrical vibrations of light rays. As a result, they absorb visible light and make the lens appear dark.

When the sunglasses are brought indoors, each Cu^{2+} ion slowly migrates to the surface of the crystal where it accepts an electron from the silver.

$$Cu^{2+} + Ag \rightarrow Cu^+ + Ag^+$$

The silver ion rejoins the crystal of the silver chloride and the darkening fades.

Marks

(*a*) What is the main difference in the darkening process for photochromic glass compared with photographic film? **1**

(*b*) (i) What evidence is there in the diagram that photochromic glass has an **amorphous structure**?

(ii) Using the representation shown in the diagram for a silica tetrahedron, draw out an arrangement that shows how six tetrahedrons might be linked together in **sand**. **2**

(*c*) (i) Why are copper(I) ions present in photochromic glass?

(ii) Write a single equation to show that the overall function of the copper(I) ions might be described as being **catalytic**. **2**

(*d*) If a colloidal silver particle has a mass of 1×10^{-4} g, how many silver atoms will it contain? **2**

(7)

[END OF QUESTION PAPER]